SPORE ASSEMBLAGES AND THEIR STRATIGRAPHICAL APPLICATION IN THE LOWER AND MIDDLE DEVONIAN OF NORTH AND CENTRAL VESTSPITSBERGEN

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ABSTRACT. Rock samples were collected from numerous stratigraphically measured sections throughout the Lower and Middle Devonian of North and Central Vestspitsbergen. An assessment has been made of the stratigraphical value of the dispersed spore content from over 250 rock samples which were prepared for microscopic investigation. Absence of spores from Andrée Land makes correlation less complete than was originally anticipated. Sections from North and Central Dickson Land have produced three distinct successive spore assemblages; the Culpa (lower) Assemblage, the Eximius (middle) Assemblage, and the Triangulatus (upper) Assemblage.

THE aim of this paper is to evaluate the stratigraphical use of the dispersed spores described earlier in this journal (Allen 1965). The author collected numerous stratigraphically placed rock specimens throughout the Lower and Middle Devonian of North and Central Vestspitsbergen, in the hope of working the complete succession for dispersed spores, and then correlating the formations on dispersed spore assemblages. Collections were made from the Red Bay Group on the east side of Raudfjorden, from the Wood Bay Formation of Andrée Land and Dickson Land, from the Grey Hoek Formation and Wijde Bay Formation of Andrée Land, and from the Mimer Valley Formation of Dickson Land (see map in Friend 1961, p. 86, fig. 2). Unfortunately spores were absent from the majority of samples collected from Andrée Land, and correlation was necessarily confined to Dickson Land. Place names in Dickson Land referred to in the text are given in text-fig. 1.

Sections collected over a wide area of Dickson Land (text-fig. 2) together represent the complete stratigraphical succession for that area. Detailed information is given in text-fig. 3, for three of these sections from Estheriahaugen, West Lagercrantzberget, and the Gonvillebreen–Stensiøbreen ridge (the top of this succession extends on to the Caiusbreen–Hoelbreen col).

Three distinct, successive, spore assemblages are distinguishable in Dickson Land, each characterized by a number of species of limited stratigraphical range, and therefore of importance for correlation within the area. To date, little work has been completed on Lower and Middle Devonian microfloras, and consequently the number of new species in Vestspitsbergen was large, and correlation with Lower and Middle Devonian spore floras from areas outside Vestspitsbergen was therefore limited. In addition to the three assemblages described from Dickson Land, productive samples were prepared from the Fraenkelryggen Formation of the Red Bay Group. Also recorded are a few ill-preserved samples from the Wijde Bay Formation, and from the highly deformed eastern portion of the Wood Bay Formation (Mimerbukta Sandstone of Friend 1961). For stratigraphical nomenclature I have followed Friend, Heintz, and Moody-Stuart (in press).

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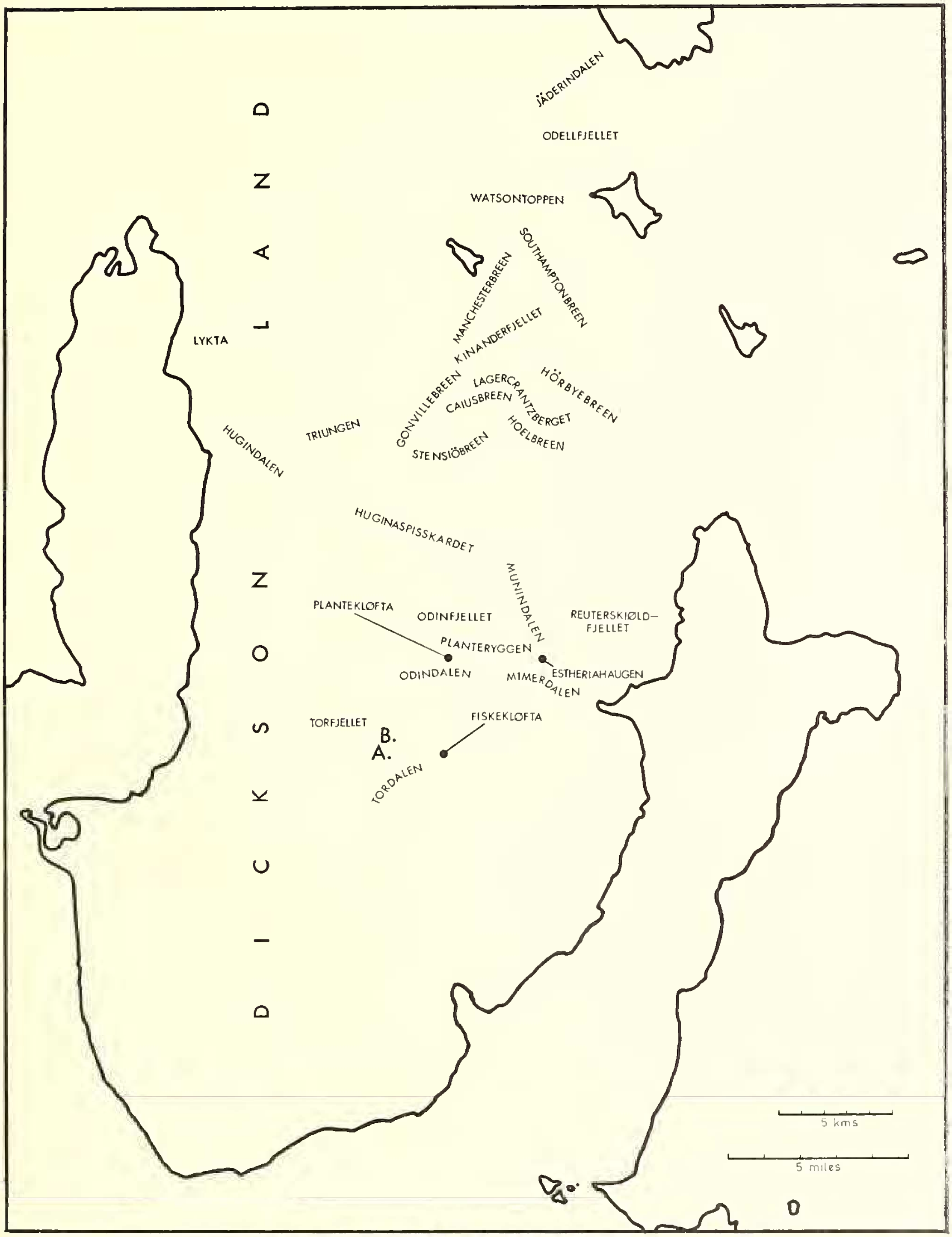
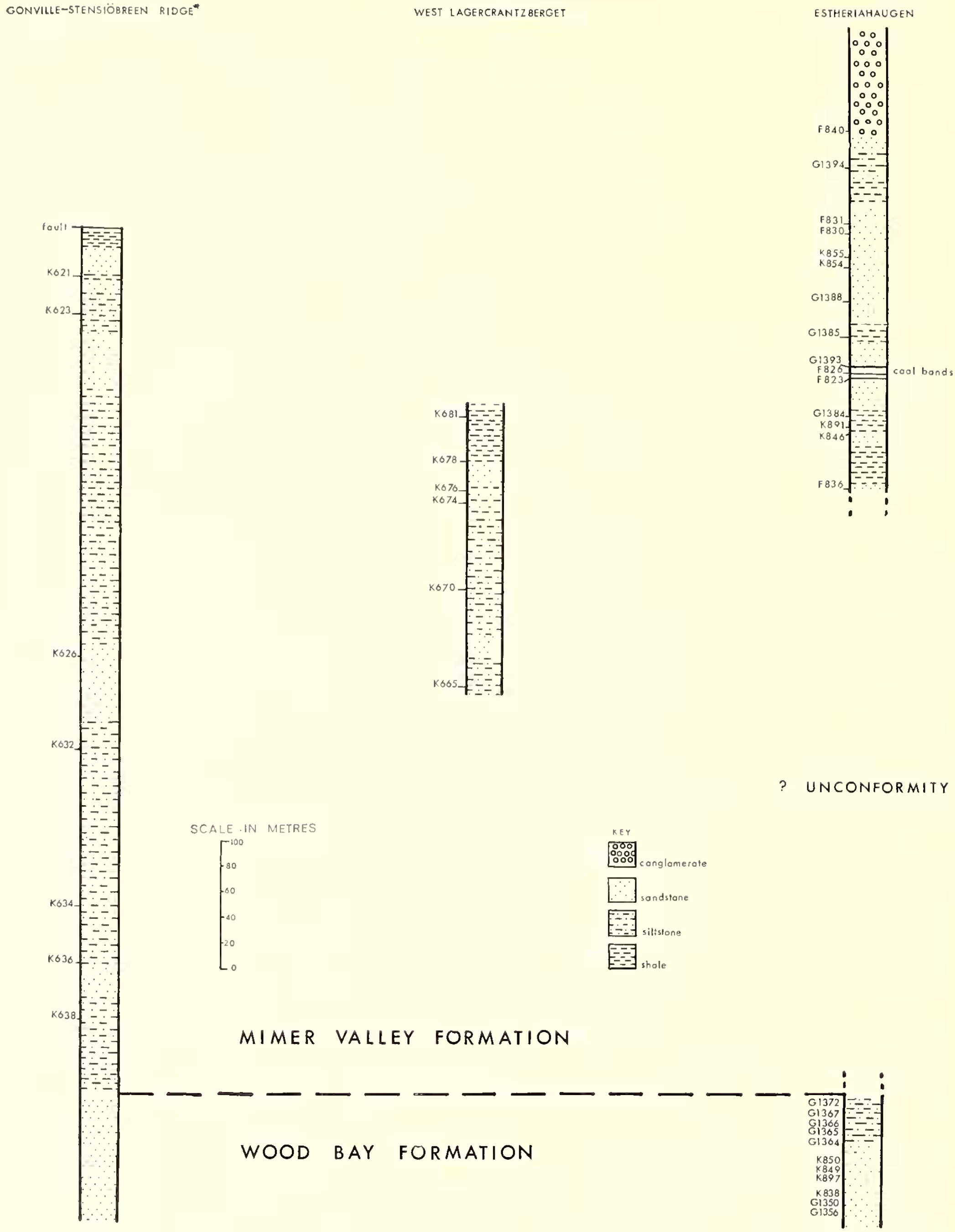
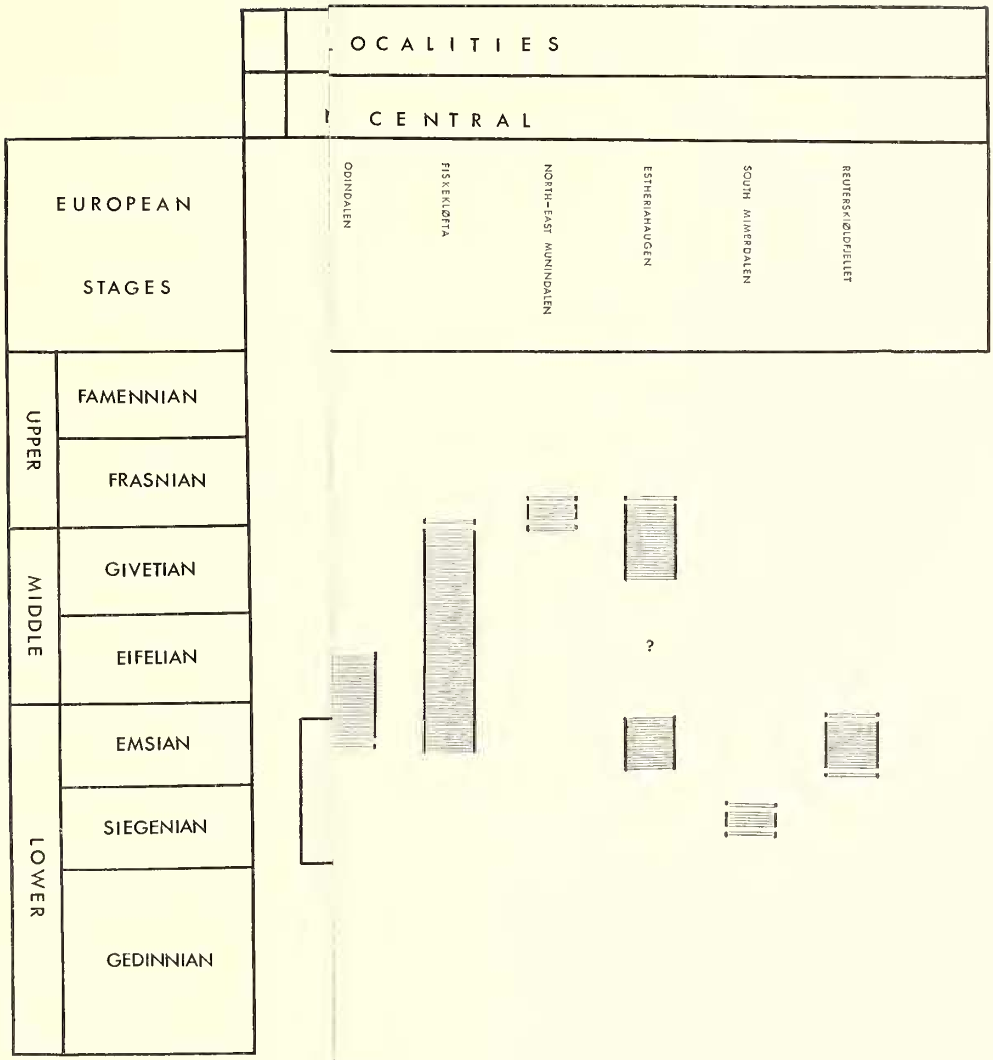


TEXT-FIG. 1. Place-names of Dickson Land referred to in the text.



TEXT-FIG. 3. Sections represented in text-fig. 2 from Gonvillebreen–Stensiöbreen ridge (the top of the succession extends on to the Caiusbreen–Hoelbreen col), West Lagercrantzberget and Estheriahaugen, giving details of lithologies, and of horizons from which samples have been prepared for microscopic investigation.


OCALITIES
CENTRAL
EUROPEAN STAGES
ODINDALEN
FISKEKLØFTA
NORTH-EAST MUNINDALEN
ESTHERIAHAUGEN
SOUTH MIMERDALEN
REUTERSKIØLDFJELLET
UPPER
FAMENNIAN
FRASNIAN
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GIVETIAN
EIFELIAN
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EMSIAN
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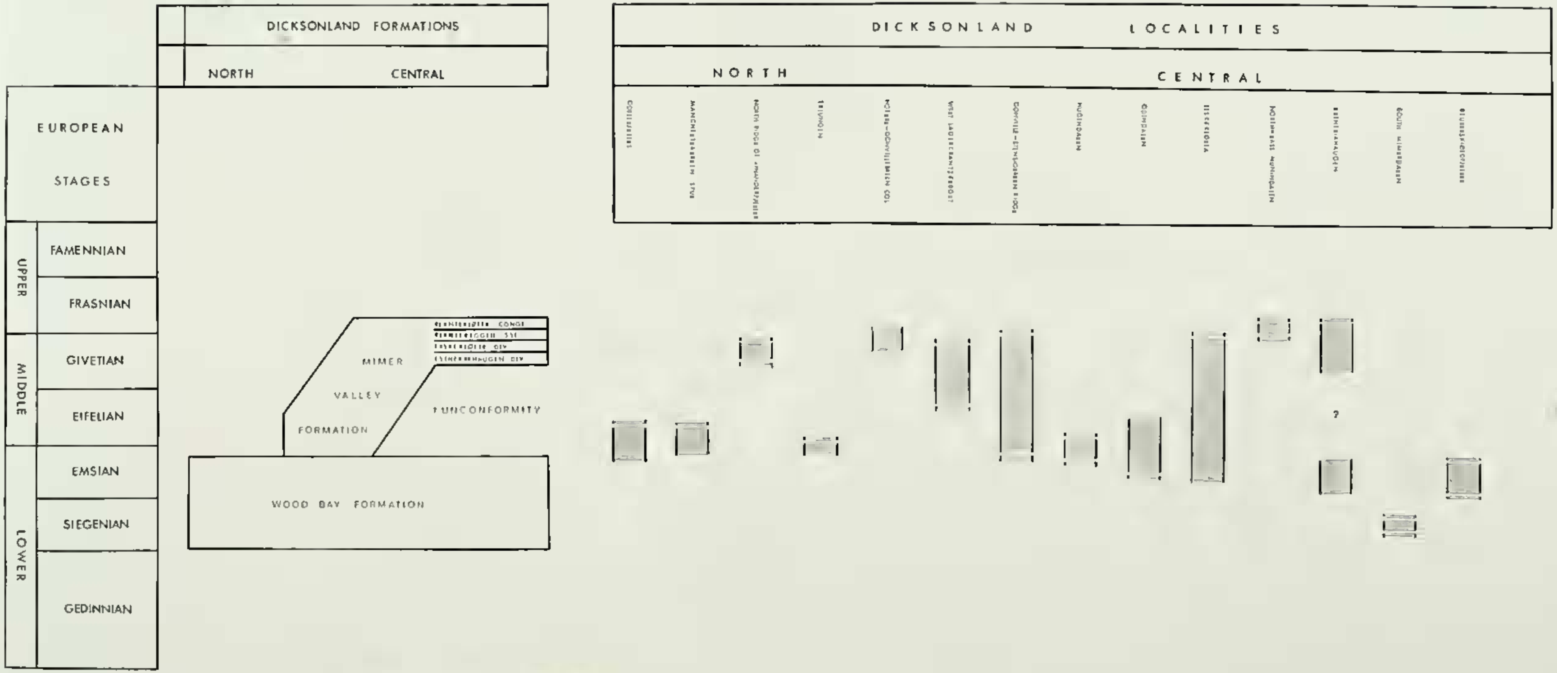


TEXT-FIG. 2. Stratigraphical columns in Dickson Land from which collections were made for palynological investigation (Stratigraphic comparison with European stages taken from Friend 1961).

THE SUCCESSION OF SPORE ASSEMBLAGES

Red Bay Group

From the Red Bay Group rock specimens for palynological investigation were only collected by the author from the Fraenkelryggen Formation. This represents the lowest horizon from which dispersed spores were obtained. This formation consists mainly of red, grey, and green sandstones and siltstones, and especially selected were the darker grey siltstone bands. The age (see Friend 1961, p. 85, for references) based on Heterostracan and Cephalaspid faunas, suggests a probable equivalent to the Upper Downtonian and Dittonian in the Anglo-Welsh area (Lower and part of the Upper Gedinnian). No diagnostic species were present however, and the assemblage was not formally named. Spores were obtained from three samples; these were poorly preserved, and of simple morphology, none being confined solely to this assemblage. The following species were recorded, together with the percentage present in each case:

	per cent.
Leiotriletes parvus Naumova 1953	4·5
Punctatisporites glaber (Naumova) Playford 1962	80·5
Punctatisporites laevigatus (Naumova) Allen 1965	1·0
Calamospora nigrata (Naumova) Allen 1965	2·0
Granulatisporites muninensis Allen 1965	1·5
Cyclogranisporites plicatus Allen 1965	6·5
Emphanisporites minutus Allen 1965	4·0

Høeg (1942, pp. 14–25) records the following macroplants from the Fraenkelryggen formation: *Pachytheca* cf. *fasciculata* Kidston and Lang; *Prototaxites sp.*; *Zosterophyllum sp.*; *Taeniocrada(?) spitsbergensis* Høeg, and *Hostinella sp.*

The Wood Bay Formation and Mimer Valley Formation of Dickson Land

In Dickson Land the lowest assemblage recorded was the Culpa Assemblage, represented only in a short section in South Mimerdalen (text-fig. 2). The Eximius and Triangulatus Assemblages, the middle and upper assemblages respectively, are best seen in sections collected from Estheriahaugen, West Lagercrantzberget, and Gonvillebreen–Stensiøbreen ridge; all the species present in these three sections are recorded in Tables 1 and 2, and wherever possible, a quantitative analysis based on 200 specimens per sample is included. Tables 3 and 4 list the species present in the Eximius and Triangulatus Assemblages from other productive, well-localized samples in Dickson Land. From a comparison of Tables 3 and 4 with text-fig. 2, it can be seen that over a wide area, the stratigraphical horizons from which these two assemblages are obtained, is extremely constant. More detailed collecting from the junctions between assemblages would probably show a more gradual change in spore composition. The assemblages are named after the most constantly occurring, easily recognizable, diagnostic species. Macroplants described by Høeg 1942 for the Wood Bay and Mimer Valley Formations of Dickson Land, are comprehensively listed in Friend 1961 (appendix, pp. 115–18).

The Culpa Assemblage. Although this assemblage is defined on the basis of only two samples from the Austfjorden Sandstone Member of the Wood Bay Formation (lower Light Member of the Reuterskiøldfjellet Sandstone of Friend 1961), it represents a more diverse assemblage than that recorded for the Fraenkelryggen Formation, and is clearly

TABLE 1. Spore distribution in samples containing the Eximius Assemblage, from a section exposed on Gonvillebreen–Stensiöbreen ridge, and from the lower portions of sections exposed on West Lagercrantzberget and Estheriahaugen. In well-preserved samples, constituent species are recorded as percentages, based on a count of 200 specimens. 'X' indicates samples in which there are too few well-preserved spores to permit a count, or where a species is present in a sample, but not in the actual count.

LOCALITY	GONVILLE–STENSIÖ-BREEN RIDGE					WEST LAGER-CRANTZBERGET				ESTHERIAHAUGEN											
SAMPLE NO.	K638	K636	K634	K632	K626	K665	K670	K674	K676	G1356	G1350	K838	K897	K849	K850	G1364	G1365	G1366	G1371	G1372	F836
Lsiotrilstss pyramidalis														2	0·5						
Lsiotrilstss psrvus												2		3			0·5				
Punctatisporitss glaber	19·5			4·5		6·5						4·5	8	7·5	8·5	20·5	18		23·5		
Punctatisporitss lasvigatus	2·5		X	2·5		X			X	X		3	7·5	7·5	2	6·5					
Punctatisporitss flavus			X			0·5															
Calamospora microrugosa		X	X	2·5		6·5	X	X	X			7		9·5							
Calamospora nigrata	4	X			X	25	X			X	X	13·5	8	4·5	3	7	15	X	36		
Calamospora witneyana		X	X																X	X	
Trilsitss oxfordisnsis		X		1·5		X		X		X		X									
Granulatisporitss muninsnsis	1·5					1						1·5				1			0·5		
Cyclogranisporitss rotundus						0·5															
Cyclogranisporitss plicatus	525	X	X	48·5	X	49	X	X	X	X	X	34	22	29	43	36	62	X	37·5	X	X
Gsminospora svalbardias									X					4·5	5·5	1·5					
Gsminospora spinosa				1·5		0·5						2									
Acanthotriletss raptus						X															
Hystricosporitss mitratus	0·5					X						1·5			1·5		X				
Bullatisporitss bullatus	0·5	X		8	X	2·5	X		X			7·5		3	3	1	1				X
Rsticulatisporites emsisnsis	X				X	X		X		X		X	X	1	0·5						
Reticulatisporites sp.	0·5	X											0·5								
Emphanisporitss rotatus												X									
Emphanisporites nsglectus	4			3·5		0·5	X			X	X		3·5		2·5	1	0·5	X	0·5		
Emphanisporites minutus										X		0·5				1					
Emphanisporites patagiatus													X	0·5		1			0·5		
Craspsdispora craspsda							X			X		6·5									
Stsnozonotrilstes furtivus	X	X			X	X				X	X		X	0·5	0·5	X					
Stenozonotrilstes insessus	3				X	2·5							1		1	1			0·5		
Stsnozonotriletss sp.	0·5					1·5						1·5	2		0·5						
Camptozonotrilstss aliquantus	0·5							X							X		X				
Archaeozonotrilstes meandricus	0·5		X	2	X	0·5		X	X						X	0·5					
Tholisporitss ancylus					X								X	0·5	0·5	1·5					
Chelinospora psrforata	0·5				X											X					
Psrotrilitss sximius	6	X	X	12	X	1	X	X	X		X	14·5	33·5	18·5	12·5	16	3	X	1	X	X
Psrotrilitss srgatus	2		X	1·5	X	1		X	X			X	7		3·5	1					
Psrotrilitss pannosus	1·5	X		1·5		1							0·5	4	10	1					
Grandispora diamphida			X	3·5			X	X				X	X	X							
Rhabdosporitss cymatilus									X					3		1					
Aulicosporitss aulicus		X		5·5		X			X	X		X		1	1	1·5					
Ancyrospora trocha									X						X						
Ancyrospora rsuta	X	X		1·5	X	X		X	X			0·5	6·5	0·5	0·5	X	X				

separable from the succeeding assemblage. This assemblage is characterized by the presence of *Lycospora culpa* Allen 1965, comprising 3 per cent. of the total spores present, together with the following diagnostic species:

	per cent.
Leiotriletes pagius Allen 1965	8·5
Emphanisporites decoratus Allen 1965	2·0
Retialetes sp. (not present in the spore count).	

Apart from the diagnostic species, the percentages of other species are very different from those in the succeeding Eximius Assemblage. Particularly high, although not so high as in the Fraenkelryggen Formation, is the proportion of simple laevigate or apiculate forms, together with representatives of the genus *Emphanisporites* McGregor 1961. Those recorded were:

	per cent.
Punctatisporites glaber (Naumova) Playford 1962	46·5
Punctatisporites laevigatus (Naumova) Allen 1965	4·0
Calamospora nigrata (Naumova) Allen 1965	8·0
Calamospora microrugosa (Ibrahim) Schopf, Wilson, and Bentall 1944	3·0
Trileites oxfordiensis Chaloner 1963	0·5
Granulatisporites muninensis Allen 1965	2·5
Cyclogranisporites plicatus Allen 1965	7·0
Emphanisporites neglectus Vigran 1964	3·5
Emphanisporites minutus Allen 1965	6·0
Emphanisporites patagiatus Allen 1965	0·5

Other morphologically more complex species present were:

Craspedispora craspeda Allen 1965	0·5
Stenozonotriletes furtivus Allen 1965	0·5
Stenozonotriletes insessus Allen 1965	2·0
Rhabdosporites cymatilus Allen 1965	0·5
Cirratriradites dissutus Allen 1965	1·5

The last named species was very rare in the succeeding Eximius Assemblage. *Leiotriletes parvus* Naumova 1953, *Leiotriletes pyramidalis* (Luber) Allen 1965, *Calamospora witneyana* Chaloner 1963, and *Emphanisporites rotatus* McGregor 1961 were also present.

The Culpa Assemblage was recorded only from the Austfjorden Member of the Wood Bay Formation, and it is probably equivalent to a Siegenian age (Friend 1961, Table 1). No spore assemblage yet described, compares with the Culpa Assemblage, but from an evolutionary viewpoint, it is interesting to note cingulate, zonate, and cavate species occurring in this low stratigraphical horizon.

The Eximius Assemblage. This assemblage (see Tables 1 and 3), was present in 77 samples, from 11 different areas in Dickson Land (those sections recorded in text-fig. 2 together with collections made by previous expeditions to West Dickson Land). The Eximius Assemblage is characterized by the presence of *Perotrilites eximius* Allen 1965, together with the diagnostic species recorded in Table 5. *Perforosporites sp.* is exclusive to this assemblage, but only two specimens have as yet been recorded. Common species which are also present in the Culpa Assemblage are recorded in Table 5.

The Eximius Assemblage is recorded from the Wood Bay Formation (the Dicksonfjorden Sandstone and Upper Reuterskiøldfjellet Sandstone of Friend 1961), Lower Mimer Valley Formation and from Vogt's bed '1' (the lowest part of the Estheriahaugen Division of the Mimer Valley Formation). The lowest beds containing the majority of species diagnostic of this assemblage, occur about 250 m. below the top of the Wood Bay Formation, probably equivalent to a Lower or Middle Emsian age (see text-fig. 2). One sample N383 from near Lykta, containing only *Bullatisporites bullatus* Allen 1965 of the diagnostic species, probably occurs slightly lower in the succession, in beds containing the 'Lykta fauna', which according to Dineley (1960, p. 31) is equivalent to

TABLE 2. Spore distribution in samples containing the Triangulatus Assemblage, from a section exposed on the Caiusbreen–Hoelbreen col, and from the upper portions of sections exposed on West Lagercrantzberget and Estheriahaugen. In well-preserved samples, the constituent species are recorded as percentages, based on a count of 200 specimens ('X', as in Table 1).

LOCALITY	CAIUS–HOELBREEN COL				W. LAGER-CRANTZB.		ESTHERIAHAUGEN													
SAMPLE NO.	K623	K621	F799	F800	K678	K681	K846	K891	G1384	F823	F826	G1393	G1385	G1388	K854	K855	F830	F831	G1394	F840
Raistrickia aratra	X			X	1	1·5	1						0·5	0·5	X				0·5	
Leiotriletes pyramidalis						X				X										
Leiotriletes parvus					X	X														
Punctatisporites glaber	3·5	4·5	X	X	8·5	5·5	4	6·5		22·5	23		7·5	2·5	X	2·5	1·5	0·5	0·5	
Punctatisporites laevigatus		1·5			0·5	0·5						X								
Calamospora microrugosa	1·5					1·5	1	1				X	1·5	1·5	0·5	1	3·5			
Calamospora nigrata														X						
Trileites oxfordiensis		0·5																		
Granulatisporites muninensis				X	3·5	4·5	3	6·5		9·5	8		26	0·5			1	2·5	2	
Cyclogranisporites rotundus	0·5	3·5		X	9·5	1·5	3	4	X	15·5	16·5	X	2·5	1·5	0·5	X	1·5	7·5	2·5	
Cyclogranisporites plicatus	1·5	7·5		X	1	3·5				2	2	X		1			0·5	0·5	1	
Geminospora tuberculata	9	6·5	X	X	6·5	1·5					0·5			0·5		2·5	3	1·5		
Geminospora svalbardiae	40·5	33·5	X	X		3·5	15	7	X	15·5	14	X	8	55·5	52	43	50·5	53·5	46	X
Geminospora spinosa															X					
Hystricosporites porcatus	11	10	X	X	X	X	0·5	X				X	0·5	3·5	7·5	2	5	1	3	X
Hystricosporites porrectus		2									X						1			
Hystricosporites monosaccus		0·5	X			X							X		0·5					
Hystricosporites corystus	3	0·5			X							X						X		
Convolutispora vermiformis								3	X	0·5	15									X
Convolutispora disparilis	5	7	X	X	9·5	3	2	7	X				27·5	6·5	18·5	12	7	14	25	X
Convolutispora mimerensis	0·5	0·5				1								0·5	0·5	1		0·5		
Convolutispora tegula		2	X	X		2·5	2·5	2·5	X	2·5	5·5			1	1·5	0·5	0·5	0·5	1·5	X
Reticulatisporites sp.					4															
Diatomozonotriletes sp.						X														
Stenozonotriletes sp.																X				
Samarisporites praetervisus		0·5																		
Samarisporites senotus				X	0·5						X	X	0·5	0·5			X		0·5	X
Samarisporites hesperus	1·5		X			0·5		0·5	X	1·5	6		0·5	2·5	2	1	3	1	4·5	X
Samarisporites triangulatus	0·5				X	0·5	X	X	X			X	5·5	9·5	3	X	6	3·5	1·5	X
Samarisporites inusitatus	0·5													1	0·5					
Densosporites devonicus	1·5		X	X					X	0·5	X	X		X	X	2	0·5		X	
Cirratriradites avius						X		0·5			X			X	X					
Camptozonotriletes asaminthus	2·5			X	3	2	4·5	1·5			X									
Archaeozonotriletes variabilis	2·5	2·5	X		3			3	X				2·5	1·5	2	4	0·5	1·5	0·5	X
Archaeozonotriletes sarus								2		1	3·5		3	1	X					
Archaeozonotriletes columnus	6·5	3·5	X	X	4	1·5	1	4						0·5	2	6	1		0·5	
Cymbosporites cyathus					2·5	2·5	10	9·5	X			X	0·5	1·5		0·5	0·5	1·5	2·5	
Cymbosporites catillus		2			34	58·5	49	40			2·5			0·5		0·5		3	0·5	
Chelinospora concinna	3	3·5	X	X	6·5	2		0·5	X				13	2·5	3	10·5	9	3·5	2·5	X
Chelinospora ligurata	0·5	1	X		X		0·5						0·5	1		3	0·5		1·5	
Auroraspora macromanifestus										5	3									
Perotrilites ergatus					X	X		X			0·5				2	0·5			0·5	
Perotrilites pannosus	1·5	0·5	X			1	0·5	1	X					2	1	5·5	3·5	0·5	2	
Grandispora inculta		0·5			1	0·5														
Calyptosporites microspinosus														X	0·5	0·5				
Calyptosporites proteus					X	X						X		X					X	X
Calyptosporites optivus	0·5	2·5												X	0·5			0·5		
Calyptosporites indolatus														X	0·5					
Rhabdosporites scamnus					1	1	2·5	X		24	13·5			1	X	0·5		2	X	
Aulicosporites vitabilis															X				X	
Nikitinsporites spitsbergensis	X	2													X					
Ancyrospora langii	3	1·5			0·5									X	1·5	1	0·5	1	1	
Ancyrospora sp.														X						

TABLE 3. Spore distribution in samples containing the Eximius Assemblage from Dickson Land (see text-fig. 2), other than those recorded in Table 1. In well-preserved samples, the constituent species are recorded as percentages, based on a count of 200 specimens ('X', as in Table 1).

LOCALITY	ODELLFJELLET						MANCHESTERBREEN SPUR						TRIUNGEN			FISKEKLØFTA						HUGINDALEN			ODINDALEN					LYKTA				REUTERSKIØLD FJELLET		
SAMPLE NO.	K501	K507	F632	K509	K515	K519	K582	K579	K577	K584	K572	K571	K645	K648	K649	K829	K716	K922	K920	K914	K753	F1597	F1598	C626	K782	K801	K806	K808	K815	G1440	G1442	N383	N372	K876	K872	K870
Leiotriletes pyramidalis																	X											0·5								
Leiotriletes parvus																											1·5		4							3
Punctatisporites glaber			10·5		3	105	14·5			8			20	105		14		2	29		3		9·5	7·5			17	11	12						4·5	16·5
Punctatisporites laevigatus	X		2	X		1·5				1	X		1·5	25		2		0·5		X		X	·5				1·5	1·5	1·5			X			2·5	3
Punctatisporites flavus					1													0·5										05								
Calamospora microrugosa				X		1	1·5	X	X	2	X	X	4·5			3·5	X									X	5		6							2·5
Calamospora nigrata	X		43	X	4·5	2·5	5·5			1	X		10·5	15·5	X	2·5	X	7·5	13	X	12·5		24·5	1 5			3·5	1·5	4·5			X			10·5	
Calamospora witneyana						X							X																			X				
Trileites oxfordiensis	X			X	X	1		X	X		X				X				1	X				X		X		1	1						X	
Granulatisporites munineneis										2			0·5		X		X	0·5	0·5		2·5	X	0·5				0·5	1								
Cyclogranisporites rotundus														1·5		3		2·5																		
Cyclogranisporites plicatus	X	X	39·5		62	40	58	X	X	60	X	X	35	41	X	47	X	62·5	46·5	X	69	X	44	63	X	X	65·5	48·5	45	X	X	X	X	X	29	69
Geminospora svalbardiae					5	1	3			2	X		5	1	X	3·5			0·5		8·5	X		0·5												
Geminospora spinosa				X	2	05			X	1·5		X	2					0·5	0·5		05											X				
Acanthotriletes raptus																		X																		
Hystricosporites mitratus					X								X			X							5·5													X
Bullatisporites bullatus		X		X	8	1·5	1·5		X	2	X		2	0·5		3	X	3·5	1·5		X	X	0·5	2·5	X	X		0·5	7			X	X	X	3	3·5
Reticulatisporites emsiensis							0·5						X	0·5		05	X		X					X			X								X	
Reticulatisporites sp.										0·5											0·5			0·5												
Perforosporites sp.						X																														
Emphanisporites rotatus					0·5								1			2																			0·5	
Emphanisporites neglectus			0·5			2·5	1·5			2	X		2·5			3·5							11·5									X				
Emphanisporites minutus																							0·5													
Emphanisporites patagiatus																																			X	
Craspedispora craspeda			1·5							7·5						0·5	X	19·5			3			2					2·5						1	
Stenozonotriletes furtivus	X			X								X	X	1		X						X		X			0·5								X	
Stenozonotriletes insessus			0·5				4		X	3·5	X		1·5	0·5		6			2				1													
Stenozonotriletes sp.		X			0·5	0·5	X		X				0·5		X	0·5						X		1	X		0·5	0·5			X					
Camptozonotriletes aliquantus										0·5							X							X											X	
Archaeozonotriletes meandricus				X	0·5	2	0·5	X		X			1	X	X	0·5		0·5									0·5								X	
Tholisporites ancylus							1						0·5	X	X		X											X							1	
Chelinospora perforata							0·5								X	X																				
Perotrilites eximius		X	2	X	8	22	4	X	X	1·5	X	X	10	17	X	7·5	X		4	X		X	2	3	X	X	2	19	14·5						36	
Perotrilites ergatus	X			X	1	2·5	1·5		X				2	1·5						X	0·5	X		3		X		3	1·5						3	0·5
Perotrilites pannosus					3	5	1·5	X	X	4	X	X	X	4					1·5			X						3							0·5	1
Grandispora diamphida				X		1·5	0·5				X	X				X						X		X												1
Rhabdosporites cymatilus							0·5						X																						X	
Aulicosporites aulicus				X	0·5	1	X			1	X		X	1·5		X								X			0·5	3							X	
Ancyrospora trocha						1·5																		2				0·5								
Ancyrospora reuta		X	0·5	X	0·5	2	X	X		X			X	1·5	X	0·5	X			X		X				X	1·5	5	0·5					X	8·5	X

uppermost Siegenian or lowermost Emsian. The highest beds containing the Eximius Assemblage, occur in Vogt's bed '1' of the Estheriahaugen Division, which is probably equivalent to an Upper Eifelian or Lower Givetian age.

The Eximius Assemblage exhibits a marked increase in diversity of spore morphology from forms present in the Culpa Assemblage, with the presence of numerous cingulate, patinate, and cavate forms, together with the first appearance of species with grapnel-tipped spines. No other assemblage yet described resembles closely the Eximius Assemblage, but as the succeeding Triangulatus Assemblage compares at least in part with Lower Givetian assemblages from the Orcadian Basin (Richardson 1960), an Emsian/Eifelian age is provisionally suggested for the Eximius Assemblage.

The Triangulatus Assemblage. This assemblage (see Tables 2 and 4) was present in 51 samples from 8 different areas in Dickson Land (those areas recorded in text-fig. 2, together with rock specimens collected by previous expeditions from Watsontoppen).

The Triangulatus Assemblage is characterized by the presence of *Samarisporites triangulatus* Allen 1965, together with the diagnostic species recorded in Table 5. The following species appear to be confined to the Triangulatus Assemblage, but are of limited occurrence: *Geminospora tuberculata* (Kedo) Allen 1965, *Hystricosporites corystus* Richardson 1960, *Samarisporites praetervisus* (Naumova) Allen 1965, *Samarisporites inusitatus* Allen 1965, *Cirratriradites avius* Allen 1965, *Archaeozonotriletes sarus* Allen 1965, *Calyptosporites indolatus* Allen 1965, *Aulicosporites vitabilis* Allen 1965, *Nikitinsporites spitsbergensis* Allen 1965, and *Ancyrospora langii* (Taugourdeau-Lantz) Allen 1965. Species common to both the Triangulatus Assemblage and the Eximius Assemblage, or common to all three assemblages are recorded in Table 5.

The Triangulatus Assemblage marked by a further increase in the number and complexity of form species, extends from Vogt's bed '2' of the Estheriahaugen Division to the top of the Plantekløfta Conglomerate at the top of the Devonian succession in Vestspitsbergen. An age equivalent to the Middle and Upper Givetian and lowermost Frasnian as suggested by Friend (1961, pp. 95–97 and Table 1), based primarily on the correlation of the Fiskekløfta Division with the Nairn Sandstone in Scotland and the Oredesch and Podsnetogor Stages of the Baltic sequence. However, Tarlo (1964, pp. 84, 85, Table 5) suggests that the Fiskekløfta Division Psammosteids are equivalent to the Tartu horizon of the Baltic sequence. This would indicate a probable Lower to Upper Givetian age equivalent for the Triangulatus Assemblage range. Evidence from the Psammosteids is supported by palynological correlation; for the Triangulatus Assemblage shows a marked similarity to an assemblage recorded by Richardson (1960), from the Eifelian–Givetian boundary in north-east Scotland. *Auroraspora macromanifestus* (Haquebard) Richardson 1960, *Calyptosporites microspinosus* Richardson 1962, and *Densosporites devonicus* Richardson 1960 occur in both assemblages, and *Samarisporites orcadensis* Richardson 1962 is very similar to *Samarisporites praetervisus* (Naumova) Allen 1965. Close comparison with Russian assemblages is more difficult, on the basis that the exact construction of the Russian species described are not always clear. The most interesting species is *Calyptosporites proteus* (Naumova) Allen 1965 which is recorded by Naumova (1953) from the Upper Givetian, and by Kedo (1955) as being an important component of the Lower and Middle Givetian, and may well prove to be an important Givetian zone fossil. Other Russian species of limited stratigraphical range

TABLE 4. Spore distribution in samples containing the Triangulatus Assemblage from Dickson Land (see text-fig. 2), other than those recorded in Table 2. In well-preserved samples, the constituent species are recorded as percentages, based on a count of 200 specimens ('X', as in Table 1). 'O', Odindalen.

LOCALITY	WATSON-TOPPEN		NORTH RIDGE OF KINANDERFJELLET						HÖRBYE-GONVILLE-BREEN COL					O	FISKEKLØFTA							NORTH AND EAST MUNINDALEN			
SAMPLE NO.	B661	B652	K559	K556	K555	K550	K558	K530	K590	F788	F790	F798	F793	K816	K720	K721	K728	K737	F1529	K738	K745	K760	K767	K772	K773
Raistrickia aratra				1·5	1		1	1·5	1	0·5					0·5	1	2	1·5		1		1·5		7	X
Leiotriletes pyramidalis						X												X							
Leiotriletes parvus				2																					
Punctatisporites glaber	2	X	X	13·5	2	6·5	1	13	2·5	2	X	4·5	0·5	8	8	3·5	2	5·5	6	3·5	X	4	5·5	4·5	2
Punctatisporites laevigatus					11·5			5	0·5											0·5		6·5			
Calamospora microrugosa					4·5		1	3·5	1·5	0·5		2	1	0·5		5	3·5	5·5		0·5		3	2·5	1·5	
Calamospora nigrata		X	X				2																	0·5	
Trileites oxfordiensis					X			1·5	X					1		X		X		X		X			
Granulatisporites muninensis				21·5	1	2·5	18·5	13·5	8·5	5·5		1	3		17·5	3·5		4	2·5			0·5	3·5	2·5	
Cyclogranisporites rotundus	3			4·5	7·5	0·5	4·5	2·5	0·5	8		0·5	3·5	0·5	3·5	4	4	4·5	2	5·5		2·5	11·5	1	
Cyclogranisporites plicatus		X	X	0·5	7			6·5	1·5							0·5		14		0·5		7		0·5	
Geminospora tuberculata	1			2·5	4	9·5	0·5	0·5	5	X		2·5	2·5	1	2			1·5		5·5		5·5	X	1	1·5
Geminospora svalbardiae	51		X	19	38	45	23·5	32·5	37·5	50	X	41·5	37	45	18	32·5	38	22·5	50	35·5	X	19·5	22·5	37	63
Geminospora spinosa				0·5								0·5							0·5						
Hystricosporites porcatus	4			0·5	3	8·5	X	25	2	3·5	X	1·5	6	2·5	2	11	2·5	5	1·5	4·5		1	1	1	4
Hystricosporites porrectus								2·5	X						X	0·5	X			X			0·5		
Hystricosporites monosaccus						X		X	X			X	X			X	X	X		1·5		2			X
Hystricosporites corystus	X				1	1·5	0·5	2	X	0·5		X	1·5	0·5		X	X	0·5	2	X	X	X		0·5	0·5
Convolutispora vermiformis								0·5	0·5														2	0·5	
Convolutispora disparilis	12			20	2	5	20·5	0·5	10·5	12·5	X	10·5	15	14·5	26	11·5	11·5	14	11·5	13	X	10	8	18·5	7
Convolutispora mimerensis	1			1		1	0·5	0·5	0·5	0·5						0·5	1			0·5		3	0·5	0·5	0·5
Convolutispora tegula					0·5	0·5	1		0·5	0·5					2		1	0·5	0·5	1·5				2·5	2·5
Reticulatisporites sp.				1																					
Diatomozonotriletes sp.						0·5																			
Stenozonotriletes sp.																				X		1·5			
Samarisporites praetervisus					0·5	1·5	X	X				0·5	0·5			0·5	0·5			X		0·5		0·5	1
Samarisporites senotus	0·5			1	0·5	X	X	0·5	1·5	X	X	1	0·5		0·5		X	0·5	1	1		0·5	2	0·5	
Samarisporites hesperus	0·5					1·5	1	2	3·5		X	1·5	2	4·5	1	0·5	2·5	1	1	2·5		8·5	20	0·5	X
Samarisporites triangulatus			X	2·5	2	2	2·5	X	5	6	X	10·5	10	5	1·5	6	13·5	X	5·5	1	X	9·5	3	0·5	X
Samarisporites inusitatus							1	1·5	0·5	1		0·5	1	1·5	5	0·5	0·5	1	0·5			1	1		0·5
Densosporites devonicus	0·5			0·5	X	X	X		1	1·5	X	X	0·5	0·5	0·5	X	X	0·5		1		2		X	1
Cirratriradites avius									X			X			X		X	X		X				X	0·5
Camptozonotriletes asaminthus							0·5																		
Archaeozonotriletes variabilis	9			2	3	0·5	2·5	2	1·5	1·5	X	2	3		2	1·5	4	1	3	2	X	2·5	3·5	1	0·5
Archaeozonotriletes sarus							0·5	1							2·5	1						1	1·5		
Archaeozonotriletes columnus	5			2	1·5	3	0·5	0·5	2	0·5	X	1·5	1·5	3	1	1	1	3	1·5	1·5	X	1	2	1	2·5
Cymbosporites cyathus				0·5	1	1·5	1		2	X			1·5	2	2	X	1·5	0·5	2	1		0·5	1·5	1·5	
Cymbosporites catillus	2			2		1	0·5	1·5		1		X		0·5			0·5	X	1						
Chelinospora concinna	7			1·5	6	1·5	8·5	1	5·5	3	X	9·5	6·5	7·5	2·5	10	6·5	8	2·5	11·5		2	7·5	10·5	9
Chelinospora ligurata	0·5					X	2·5		0·5	0·5		0·5	X	0·5	1	X	0·5	1·5	2	1		0·5	0·5	1·5	
Auroraspora macromanifestus																	0·5	X		0·5		X			
Perotrilites ergatus										X		X		1		0·5			0·5	X		X		X	
Perotrilites pannosus					2	3·5	4·5	0·5	4·5	X		4·5	2·5	0·5	1	2·5	1·5	3·5	2	3·5		0·5		2·5	2·5
Grandispora inculta																	X			X					
Calyptosporites microspinosus									X	X		0·5	X	X		X		X		X					
Calyptosporites proteus			X			1														X					
Calyptosporites optivus	0·5					0·5	X	0·5	X	X		0·5	X	X		X	X		0·5	X		X		X	X
Calyptosporites indolatus					X			X	X	X		X	X	X		X	X	X		X				X	X
Rhabdosporites scamnus					X		X	0·5	X	0·5	X	2				X	1·5		0·5	X		1·5			X
Aulicosporites vitabilis					X			X	X							1				X					
Nikitinsporites spitsbergensis					X	X			X									X	X			X			
Ancyrospora langii	0·5				0·5	1·5	X		X	0·5		0·5	0·5	X		1·5	X	0·5		X	X	1		1	1·5
Ancyrospora sp.					X	X			X									X		X		X		X	

present in Spitsbergen include *Geminospora tuberculata* (Kedo) Allen 1965, which is recorded by Kedo (1955) from the top of the Givetian, and *Calyptosporites optivus* (Chibrikova) Allen 1965 which is recorded from the Frasnian. From a general similarity of spore forms with those of Richardson (1960) and Kedo (1955), and the evidence of

TABLE 5. Important constituent species of the three assemblages described from the Lower and Middle Devonian of North and Central Vestspitsbergen. The horizontal lines indicate the presence of a species in an assemblage, and not its stratigraphical range within that assemblage.

MICROFLORAL ASSEMBLAGE	TRIANGULATUS	EXIMIUS	CULPA
SUGGESTED AGE	GIVETIAN	EMSIAN, EIFELIAN	MIDDLE AND UPPER SIEGENIAN
Hystricosporites porcatus	—		
Hystricosporites porrectus	—		
Hystricosporites monosaccus	—		
Raistrickia aratra	—		
Convolutispora disparilis	—		
Convolutispora mimerensis	—		
Convolutispora tegula	—		
Samarisporites senotus	—		
Samarisporites hesperus	—		
Samarisporites triangulatus	—		
Densosporites devonicus	—		
Camptozonotriletes asaminthus	—		
Archaeozonotriletes variabilis	—		
Archaeozonotriletes columnus	—		
Chelinospora concinna	—		
Chelinospora ligurata	—		
Cymbosporites cyathus	—		
Cymbosporites catillus	—		
Grandispora inculta	—		
Calyptosporites microspinosus	—		
Calyptosporites proteus	—		
Calyptosporites optivus	—		
Rhabdosporites scamnus	—		
Geminospora spinosa	—	—	
Geminospora svalbardiae	—	—	
Stenozonotriletes sp.	—	—	
Perotrilites ergatus	—	—	
Perotrilites pannosus	—	—	
Hystricosporites mitratus		—	
Bullatisporites bullatus		—	
Reticulatisporites emsiensis		—	
Camptozonotriletes aliquantus		—	
Archaeozonotriletes meandricus		—	
Tholisporites ancylus		—	
Chelinospora perforata		—	
Perotrilites eximius		—	
Grandispora diamphida		—	
Aulicosporites aulicus		—	
Ancyrospora trocha		—	
Ancyrospora reuta		—	
Emphanisporites neglectus		—	—
Emphanisporites minutus		—	—
Craspedispora craspeda		—	—
Stenozonotriletes furtivus		—	—
Stenozonotriletes inaessus		—	—
Cirratriradites dissutus		—	—
Rhabdosporites cymatilus		—	—
Leiotriletes pagius			—
Emphanisporites decoratus			—
Lycospora culpa			—
Punctatisporites glaber	—	—	—
Punctatisporites laevigatus	—	—	—
Calamospora nigrata	—	—	—
Calamospora microrugosa	—	—	—
Granulatisporites muninensis	—	—	—
Cyclogranisporites plicatus	—	—	—

the Fiskekløfta Division psammosteids, a Givetian age equivalent is provisionally suggested for the Triangulatus Assemblage.

Other productive samples

Wood Bay Formation—deformed eastern portion (Mimerbukta Sandstone of Friend 1961). Thirteen samples collected from Karnakfjellet, East Lagercrantzberget, and Mimerbukta were prepared, of which six produced a few poorly preserved, morphologically simple spores. These spores cannot be included within any one of the described assemblages. Spores present were *Punctatisporites glaber* (Naumova) Playford 1962, *Punctatisporites laevigatus* (Naumova) Allen 1965, and *Cyclogranisporites plicatus* Allen 1965.

Widje Bay Formation. Of the twenty-eight samples prepared, six produced a few ill-preserved spores. These were: *Leiotriletes parvus* Naumova 1953, *Punctatisporites glaber* (Naumova) Playford 1962, *Calamospora nigrata* (Naumova) Allen 1965, *Granulatisporites muninensis* Allen 1965, *Geminospora svalbardiae* (Vigran) Allen 1965, and *Cyclogranisporites plicatus* Allen 1965.

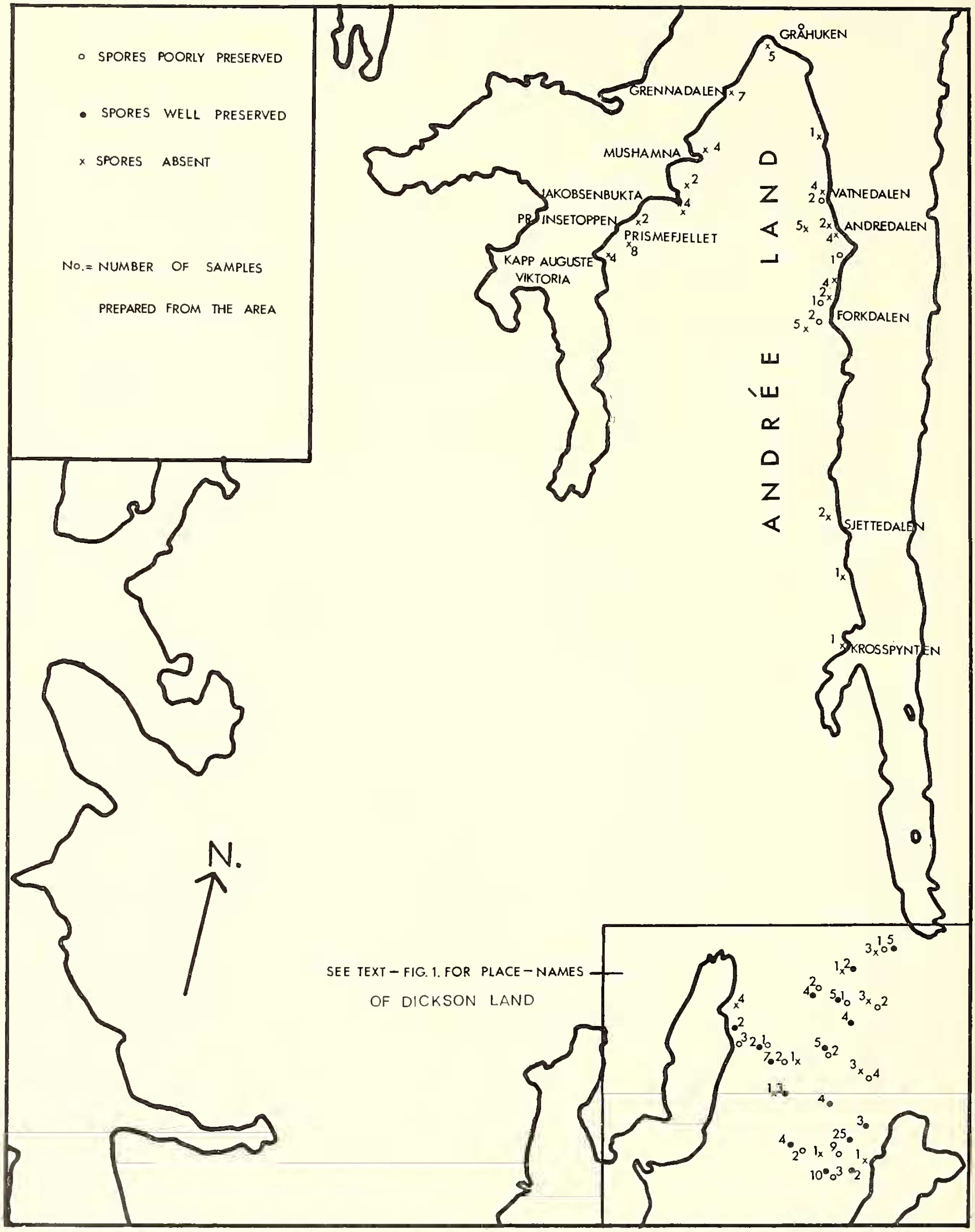
No diagnostic species were present, and the assemblage cannot be related to any one of the described assemblages. With 75 per cent. of the spores being *Punctatisporites glaber* (Naumova) Playford, and the rest of a very simple construction, this poorly preserved assemblage resembles most closely that of the Fraenkelryggen Formation, which is clearly considerably older.

ABSENCE OF SPORES IN ANDRÉE LAND

From numerous localities and horizons within Andrée Land (text-fig. 4), 73 rock specimens were macerated from which only 6 (all from the Wijde Bay Formation) produced spores. These were ill-preserved, few in number, and of a simple morphographic nature. Many of these samples did, however, produce poorly preserved tracheids and cuticle fragments. This compares with 138 rock specimens prepared for microscopic examination from Dickson Land, of which only 18 failed to produce any spores, and of the remainder 93 produced moderately well preserved and diverse species.

Of the Andrée Land specimens prepared, 42 were from the Grey Hoek Formation, 28 from the Wijde Bay Formation, and 3 from the Wood Bay Formation. From the palaeo-ecological aspect, samples from every lithology present in Andrée Land were prepared; these included black shales, dark grey-green and red siltstones and sandstones, and ferruginous nodules. From the depositional aspect, specimens were selected for their high or low micaceous and calcareous contents, and for size of plant remains, from specimens with very large plant fragments down to those with only carbonaceous specks. Specimens with well-preserved plant or fish fragments were especially selected, and badly weathered material was not used. Much experimentation in timing and concentration of chemicals in the preparation of samples, suggests that the preparation technique was not at fault.

Absence of spores from the red beds in the Wood Bay Formation in both Andrée Land and Dickson Land, is probably the result of depositional or post-depositional lateritic and oxidizing conditions, whereas their absence from non-red Wijde Bay and Grey Hoek Formations is more surprising. If, as Friend (1961) suggests, these beds



TEXT-FIG. 4. Localities in Andrée Land and Dickson Land giving details of spore presence and absence.

represent a marginal marine area, then it is unlikely that they would produce spores in the same quantity, or of the same diverse morphology, as those from the Mimer Valley Formation, which probably represents an area of inland rivers and stagnant lakes (Friend 1961). However, abundant plant fragments are present throughout the Wijde Bay and Grey Hoek Formations, and it seems very probable that spores were commonly deposited within this sequence. Sub-aerial weathering has some effect, but unweathered samples were carefully selected, and specimens from Andrée Land are certainly no more weathered than productive Dickson Land samples. Two possibilities would appear to remain; either there has been an increase in thickness of post-Devonian sediments northwards, the greater overburden causing disruption of the spore exine, or there has been increased tectonic activity in Andrée Land. There is no evidence for greater thickness of post-Devonian deposits to the north in Andrée Land (Orvin 1940), and during Carboniferous and Permian times, the main basins of deposition were to the south of Andrée Land (Cutbill and Challinor 1965, pp. 425–31). A tectonic cause seems more probable; absence of spores from the deformed eastern part of the Wood Bay Formation in Dickson Land (Mimerbukta Sandstone of Friend 1961), is certainly due to their deformed state, and although the Wijde Bay and Grey Hoek Formations have not suffered deformation to the same extent, there have frequently been small movements along the bedding planes. It may be a certain type of deformation that destroys spores, for in Dickson Land spores have been obtained from vertical and slightly overturned beds. Before a more definite hypothesis can be put forward, further sampling must be carried out in the critical, rather inaccessible, area of North Dickson Land and South Andrée Land.

CONCLUSIONS

The Spitsbergen succession is particularly important as a spore assemblage/stratigraphical study, in that it represents one of the few Devonian continental successions extending from Lower Devonian into Middle Devonian without a stratigraphical break. According to Vogt (1941) there is an unconformity between the Wood Bay and Mimer Valley Formations in Mimerdalen, but neither Friend (1961, p. 95) nor the author could find any evidence of this within the Estheriahaugen section. Further more detailed subdivision of the Eximius Assemblage may help to solve this problem.

Of the three successive assemblages described herein, the Triangulatus Assemblage is compared in part with assemblages from the Lower Givetian of Russia, and with the Upper Eifelian and Lower Givetian of Scotland. The Culpa and Eximius Assemblages cannot be closely compared with previously described Devonian assemblages. The diversity of spore forms particularly in the Eximius Assemblage, suggests that during Lower Devonian times, Spitsbergen supported a relatively advanced land flora.

The vertical distribution of dispersed spores provides a useful means of correlation within Dickson Land. This is particularly important in an area where fish fragments may be sparse or only locally abundant.

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